F. **Warning Labels Are Not the Appropriate Mechanism To Achieve Enhanced Reliability of LMS Systems.**

The Commission seeks comment on measures that should be taken to protect the public from the potentially harmful effects of system failure due to interference from lower priority users of the 902-928 MHz band (i.e., amateur radio and Part 15 devices), as well as from Federal Government Radiolocation stations and ISM devices. Notice at ¶¶ 23-24. In particular the Commission cites new, spread spectrum Part 15 equipment operating with up to one (1) watt power as a potential source of future interference. As a remedy, it proposes a warning, to be printed in all literature accompanying LMS equipment, advising the user that interference from Federal Government operations and ISM devices might cause "undesired operation" of the LMS equipment.

MobileVision believes the proposed warning is misdirected and fails to address the interference problem experienced by providers. It strongly recommends that the proposal in the NPRM with respect to requiring the warning not be interference would be eliminated. Narrowband tag reader advocates the Commission proposes to preclude the grant of future requests for extended implementation periods, while preserving in effect any prior grants of such requests that remain operative.

The complexity and size of LMS systems today has been previously discussed here and is well known to the Commission, which noted the "often extensive infrastructure and high capacity of many AVM systems" in connection with its proposal to license LMS systems on a private carrier basis. *Id.* at ¶ 8. The design of each of MobileVision's systems consists of multiple tower sites and transmitters, interconnected with a central office. Moreover, systems are, and indeed must be, designed to serve several metropolitan areas throughout a region in order to provide the scope and range of services that the public needs and that commercial viability demands. MobileVision, therefore, respectfully recommend that the Commission modify its proposal as to construction period limits for wide-area wideband LMS systems.[39]

Continued from previous page
periods being discussed in the text and the footnote or is meant to have a broader application. In any event, it is MobileVision's contention that licensees such as MobileVision and Teletrac, which have expended massive effort and expense during the 18 year period of the interim rules in developing, licensing and implementing their technology in reliance on those rules, may not now be compelled to operate in a fashion inconsistent with those rules, except in ways explicitly set forth in the Notice and upon which there has been an opportunity to comment.

39 Imposition of an eight month construction limit on narrowband systems like toll booth operators may be logical and feasible, in view of the more localized nature of such systems.

Teletrac, in its Petition, and MobileVision, in its supporting comments, recommended that the Commission adopt a ten-year build out period for licensees holding authorizations in multiple markets.[40] In light of the Commission's proposal to defer licensing of additional LMS systems for a period of five years within 110 miles of an existing licensed co-channel facility, MobileVision recommends that the Commission adopt, in lieu of the 10-year buildout period, a construction period tied to the 5-year deferred licensing scheme. To assure that spectrum does not remain unused for inappropriate periods of time and that wideband LMS services are made available to the public expeditiously, the 5-year period, which would run from the date of the Report and Order in this proceeding, should include benchmarks annually, beginning at the end of the second year, requiring the licensee to certify as to construction in 40%, 60%, 80% and 100% of its licensed markets, i.e., the 110-mile radius areas, at the end of the second, third, fourth and fifth year, respectively.[41] Failure to meet the required benchmarks would result in forfeiture of authorizations for unconstructed systems. In this fashion, frequencies held by those lacking the resources or intent to

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40 Teletrac Petition at 32-33; MobileVision Comments on Teletrac Petition at 16-17.

41 The approach is similar to that adopted by the Commission in

construct would become available again within a reasonable time for licensing to others.[42]

H. The Commission Should Adopt Its Proposed Technical Requirements, Except For Its Proposed Power Limitations and Out-Of-Band Interference Measurement.

The Commission has proposed a number of technical requirements with respect to the operation of LMS systems. These involve type acceptance of LMS equipment, the type of permissible emissions, bandwidth limitations, frequency tolerances, maximum peak effective radiated power and out-of-band emissions. The Commission has proposed the following specific, technical limitations:

1. Maximum Bandwidths

for 904-912 and 918-926 MHz	- maximum 8 MHz
for 902-904 and 926-928 MHz	- maximum 2 MHz
for 912-918 MHz	- maximum 6 MHz

2. Frequency Tolerance

for 904-912 and 918-926 MHz	- .0005 percent
for 902-904 and 926-928 MHz	- no minimum tolerance
for 912-918 MHz	- no minimum tolerance

3. Maximum Peak Effective Radiated Power for 902-928 MHz - 300 watts

MobileVision supports the first two of the above-listed proposals. MobileVision is currently authorized to operate under the interim rules at up to 500 watts of power and is unaware of any stated concerns by the Commission that support a reduction in this

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42 As to any licenses issued following the 5-year period of deferred licensing, MobileVision supports the Commission's proposal to impose an 8 month construction period.

authorization. Any concerns that may arise should be adequately addressed by the limitations on out of band emissions.[43]

In addition, the Commission has proposed that no restrictions be placed on the type of emissions permitted for LMS operation, and MobileVision fully supports this proposal. As discussed above at pp. 12-16 and 38, many customers of LMS services desire a package of services. In order to provide these services in different packages, it is important that LMS operators have the flexibility to use whatever types of emissions they require in the authorized band. Therefore, MobileVision fully supports this flexibility.

With respect to type acceptance of LMS equipment, the Commission has proposed that LMS equipment be type accepted prior to use to ensure compliance with the technical requirements. MobileVision supports type acceptance of LMS equipment, but notes that such type acceptance will not remedy nor reduce the interference between narrowband and wideband LMS systems that are co-channel with another wideband LMS system.

Finally, the Commission has proposed to limit emissions outside the authorized bandwidth to at least 55 + 10log(P) dB, where P is the highest emission (in watts) of the transmitter

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43 The Notice contains a request for comments on whether the wideband systems should be required to distribute power evenly throughout their bandwidth. MobileVision is unclear as to the intent of the Commission's request and unaware of any concern that should result in such a requirement. In any event, MobileVision opposes such a requirement as unduly restrictive of the flexibility, provided elsewhere in the rules, for the design and operation of LMS systems. As noted, MobileVision does support out of band emissions requirements measured at the edge of the bandwidth.

inside the authorized bandwidth. MobileVision opposes the Commission's proposal for measurement of out-of-band emissions. This proposed measurement does not deal with spread spectrum signals effectively.[44] Specifically, the power in a spread spectrum signal depends on its bandwidth. By their nature, spread spectrum systems distribute power over a large bandwidth compared with traditional narrowband systems. For example, when measuring the peak power of a spread spectrum signal on a spread spectrum analyzer, the measured peak power will vary depending on the bandwidth chosen for that measurement on the analyzer. Therefore, MobileVision proposes a method based on measuring out-of-band emissions expressed in watts/Hz; this method is a common way to measure the power in a spread spectrum signal.

III. CONCLUSION

MobileVision supports the adoption of permanent rules in Part 90 governing the provision of location and monitoring services, in conjunction with ancillary communications services, to the public. Therefore, MobileVision urges the Commission to adopt the proposals set forth in the *Notice*, as modified by

[44] *See* Technical Appendix, Section V.

MobileVision, for the allocation of spectrum and the licensing and technical operations of LMS systems.

Respectfully submitted.

A

TECHNICAL APPENDIX TO COMMENTS OF MOBILEVISION, L.P. In the Matter of Amendment of Part 90 of the Commission's Rules to Adopt Regulations for Automatic Vehicle Monitoring Systems, PR Docket No. 93-61 RM - 8013, filed June 29, 1993

This Appendix is offered as additional technical background to the Comments filed by MobileVision in this proceeding. It is intended to supplement the Overview of Wide-Band Pulse-Ranging Spread Spectrum Technology and the Discussion of the Proposed Rules contained in the Comments and is not intended to fully describe the applicable technology without reference to those Comments. Rather, it contains more complete explanations of the technical facts and engineering considerations upon which the MobileVision Comments are based.

The technical matters described herein are arranged under the following headings:

I. Ranging Accuracy/Required Bandwidth
II. Number of Stations/Position Accuracy
III. Need for Interference Free Operation
IV. Capacity Control Mechanisms
V. Out of Band Transmission Measurement

I. Ranging Accuracy/Required Bandwidth

The purpose of a location system is to accurately locate objects within its coverage area. A figure of merit of performance of such a system is the accuracy it achieves. Clearly, a system which does not locate a stolen vehicle, a vehicle in distress, or a fleet operator's vehicles accurately would have little worth.

The MobileVision system uses direct sequence spread spectrum (DSSS) techniques to perform mobile unit location. To implement a DSSS system, a pulse is "chipped" by a pseudo-noise sequence which then modulates a radio frequency carrier thus causing the energy contained

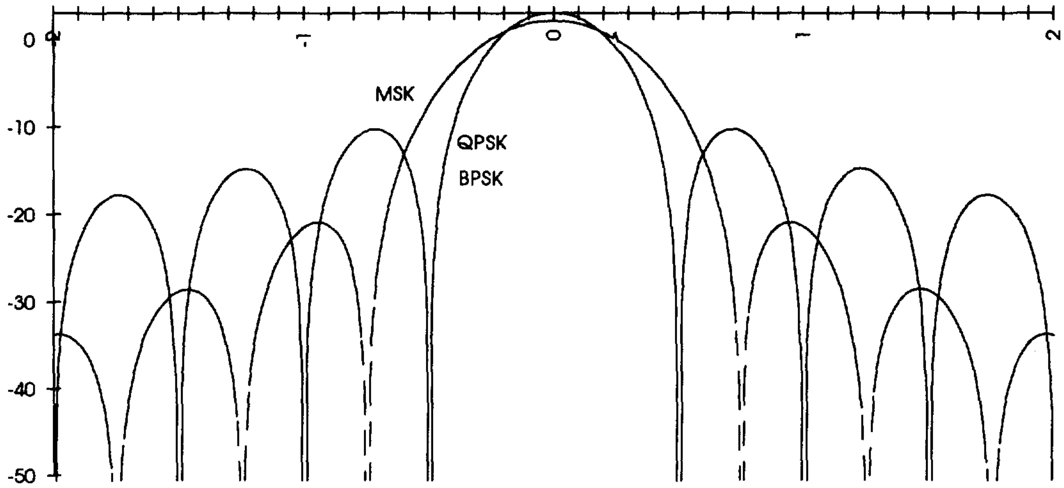
- the period of the chipping sequence.

Timing jitter is inversely proportional to the length of the spread spectrum burst, t_p, i.e., the longer the burst the better. The longer the burst the more integration (or averaging) of the correlated sequences takes place. Longer bursts, however, directly reduce the system's

The r.m.s. timing jitter, then, is inversely proportional to the square root of the product of the these three factors. Although it is possible to increase the burst duration (t_p), this adversely affects system capacity. Thus designers will keep t_p as short as possible even though this decreases measurement accuracy. In the current environment, designers can do little to prevent harmful interference from degrading the received signal to noise ratio. The only factor left to adjust, then, is the chipping sequence frequency, f_c. Adjusting this frequency to the highest value possible consistent with bandwidth allocation is the most effective means of ensuring high measurement accuracy.

The accuracy of a spread spectrum location system is related to the chipping sequence frequency fc , of the spreading signal and the duration of the transmitted signal. Fc, also known as the chip rate, equals 1/Tc where Tc is the time of a chip. For instance, for the same length signal burst, the faster the chip rate the better the accuracy. Conversely, if the chip rate is reduced, then in order to achieve the same accuracy, the length of the burst will need to be increased. The longer the transmitted burst, however, the less the system capacity. Thus it is desirable to keep the transmission burst length as short as possible.

In order to obtain the highest system capacity, therefore, it is desirable to make the spread spectrum transmission as short as possible, and this means that the chip rate should be as high as possible. The where the width of the main lobe is 2/Tc, and the first sidelobes are 1/Tc wide (see diagram below). The MSK spectrum has a wider main lobe but lower sidelobes.



Unfiltered BPSK, QPSK, MSK Spectra

The peak value of the first sidelobes for BPSK/QPSK is typically -13.5 dB, relative to the peak value of the main lobe. Filtering of the pulse sequence can reduce the sidelobes considerably, but when amplified by a limiting amplifier, the sidelobe levels become higher again. This is due to amplitude modulation being present in the waveform. For both Offset QPSK and MSK the resulting level of the sidelobes after filtering and limiting, are about -30 dB relative to the peak. (see: Morais and Feher, "The Effects of Filtering and Limiting on the Performance of QPSK, Offset QPSK, and MSK Systems", IEEE Trans. Comms, Vol. Com-28, No. 12, 1980).

It is possible to filter the sidelobes and/or to use linear amplifiers to keep the level of the sidelobes at a minimum but:

a) the size, weight and cost of the necessary filters, and,

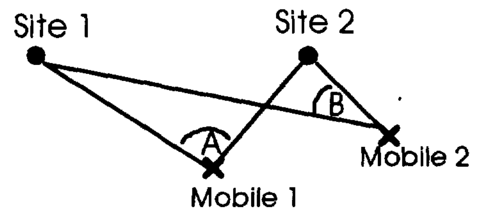
b) the power consumption, cost and size of the linear amplifier, render both filters and linear amplifiers prohibitive on both technical and cost grounds for a marketable, mobile radio. For example, MobileVision fixed site filter assemblies are quite large (about 36 inches high and 19 inches wide), heavy (about 50 pounds) and expensive. It would not be possible to mount these filters in a consumer's vehicle.

Generally in a location system, the spread spectrum signal is transmitted by the mobile unit which is required to be a low cost device. There is no known cost effective technique that will attenuate the sidelobes to a level that would not cause interference, or to allow for the ancillary communication services needed to serve the public and for cost effectiveness of the system. Therefore, it is necessary to include the first sidelobes within the allocated bandwidth. Thus, with an allocation of 8 MHz bandwidth, the maximum chip rate is in the order of 2 million chips per second.

II. Number of Stations vs. Position Accuracy

Number of Stations

The technique used by spread spectrum location systems is known as "time of arrival difference" or "hyperbolic position determination". The difference in time of arrival of the mobile transmission is measured at a number of receiving stations and the location computed from these measurements. A location estimate derived from the time of arrival difference at a triad of sites will be positioned at the intersection(s) of two hyperbola. Unfortunately there are two points of intersection. If the distances to the sites are large, such as those encountered in a LORAN system, then it is simple to distinguish between the actual location and the other solution. In a city location system operating at 900 MHz, however, the receiving sites will be relatively close together and it is not always possible to calculate the correct solution from error is related to the angle between the pair of receiving sites measured from the transmitter, as shown in Figure 1.



GDOP Error	
Angle	K=
10°	5.4
20°	3.3
30°	2.2

Fig. 1 - Angle between Sites

If the angle subtended to the two sites by the transmitter is 30 degrees, then the r.m.s. location error is effectively multiplied by 2.2. This approximately equates to an area of + 60 degrees, behind the sites. Figure 2 below shows the approximate value of K, the GDOP coefficient, that results from a location calculation of a mobile that is behind one of the sites.

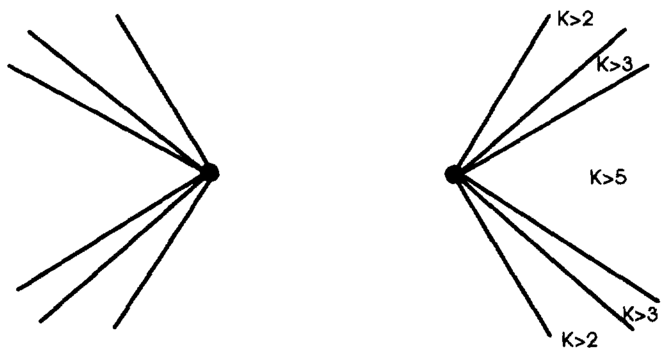


Fig 2 - Area of GDOP Error K

Thus, when laying out the sites, it is important to ensure that the angle A or B in Figure 1, is greater that 20° and, if possible, greater than 30°. Therefore, the internal angle between any three sites should be less than 150°, as shown in Figure 3.

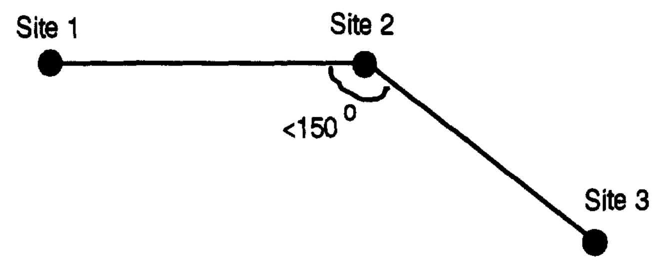


Fig 3 - Angle to be less than 150° for good GDOP

Position Accuracy

From the above it can be seen that the position accuracy is affected by

III. Need For Interference Free Operation

As described in the prior sections, timing jitter degrades accuracy and increases in inverse proportion to signal to noise ratio. Since interference decreases signal to noise ratio, it increases timing jitter and thus decreases system accuracy. The extent to which interference does so is affected by several factors including propagation loss, jamming margin, and the near far problem.

Propagation Loss

When predicting the received level of a transmitted signal it is necessary to calculate the propagation loss. The accepted formulas for the prediction of propagation loss in an urban environment are those in CCIR Recommendation 370-1 which are based on the Okumura prediction method (see: Y. Okumura et al., "Field strength and its variability in UHF and VHF land mobile service", Review of the Electrical. Communications Laboratory, vol. 16, 1968). An empirical formula for propagation loss, derived from Okumura's report has been produced by Hata (see: M. Hata, "Empirical Formula for Propagation Loss in Land Mobile Services", IEEE Trans. on Veh. Tech., vol. VT-29, No. 3, 1980). This formula has become a standard in planning for land mobile systems.

In the Hata formula the propagation loss due to distance is:

$$(44.9 - 6.55 \log h_b) \log R$$

where h_b is the base station antenna height (m)

and R is the distance (km)

Thus for a 100 ft (30m) mast, the loss is 35.22 log R and for a 300 ft mast, the loss is 31.8 log R. Therefore, the propagation loss, in an urban area, is between $R^{3.5}$ and $R^{3.2}$.

Thus an interfering signal source located one mile from the receiving site will be received about 10.56 ($2^{3.4}$) times stronger than a desired signal located two miles from the receiving site, i.e., 10.2 dB higher.

Jamming Margin

A spread spectrum signal has what is known as a "Jamming Margin". This is the residual advantage that the system has against a jammer and/or noise. This is defined as:

$Mj = PG - L - (SNR_O)$ (in dB)

where , PG is the processing gain,

L is system loss, and,

SNR_O is the output signal to noise ratio

(see: "Modern Communications and Spread Spectrum", G R Cooper, McGraw-Hill, 1986).

The Jamming Margin can also be defined as:

$Mj = PG - (E_b/n_oj) - L$ (in dB)

This is the residual advantage that the system has against a jammer after we subtract both the minimum required energy/bit-to-jamming noise power spectral density ratio (E_b/n_oj) and implementation and other losses L. (see:, "Theory of Spread-Spectrum Communications - A Tutorial", R L Pickholtz et al, IEEE Trans. on Comms., Vol. Com-30, No. 5, 1982).

The Processing Gain (PG) is the ratio of the signal bandwidth to the message bandwidth. For direct sequence spread spectrum systems used for location, where the correlation of every code sequence is required, the maximum PG is 10 log N dB, where N is the length of the spreading code.

BPSK, QPSK and MSK modulation all require the same ratio of energy per bit/noise for a specified bit error rate (theoretically 9.5 dB for 10^{-5} BER). MSK requires 1.33 times the signal to noise ratio. Assuming a BPSK modulation, a practical output signal to noise ratio of 12-15 dB is required in order to obtain a satisfactory BER.

For a spreading code (chipping sequence) length of 63 the practical jamming margin is therefore on the order of only 6 dB. Therefore any received interfering signal, 6 dB higher, will block the wanted or desired signal.

It should also be noted that as the length of the chipping sequence increases, so does the need for tighter frequency control on the transmission. The more accurate the frequency required in the mobile

Interference Ratios, Near-Far Problem.

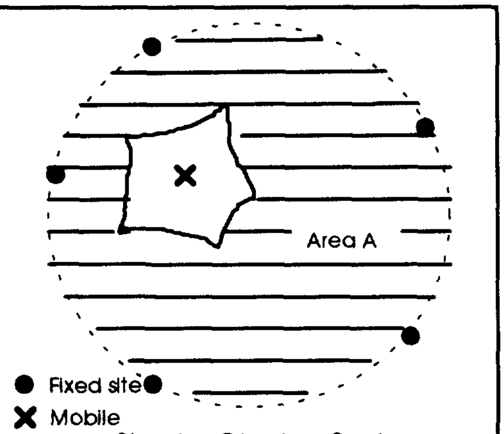
The following tables show the minimum acceptable ratio of the distances of the unwanted (Du) and the wanted (Dw) signals, assuming that the transmitted power of the unwanted signal is the same as that of the wanted. This is the near-far problem.

Code Length	(SNR)o dBs	PG max (dBs)	Du/Dw
1024	10	20.10	3.90
512	10	17.09	3.18
255	10	14.07	2.59
127	10	11.04	2.11
63	10	7.99	1.72

Code Length	(SNR)o dBs	PG max (dBs)	Du/Dw
1024	15	15.10	2.78
512	15	12.09	2.27
255	15	9.07	1.85
127	15	6.04	1.51
63	15	2.99	1.22

Thus for a code length of 63 and a required SNR of 15 dB, the ratio of Du/Dw is only 1.22. This means that if the wanted signal is 5 miles away from the receiving site then any unwanted in-band transmission within 4.1 miles of the receiving site will jam the wanted signal. If the unwanted signal is transmitted at a power of 3 dB higher, then it will block the wanted if it is within 5 miles of the receiving site.

It should be remembered that in a spread spectrum location system, it is desirable that the signal be received at as many sites as possible. Therefore it is apparent that several sites will be at a significant distance from the wanted transmission. This will exacerbate the problem. Consider the single cluster system shown below.



Single Cluster System

The diagram above shows a typical situation where the mobile is located within a cluster of receiving sites. Any interfering transmission within the shaded area, area A, will block the wanted signal at one or more of the receiving sites. Thus, if this vehicle was working in a shared environment, where other vehicles were transmitting interfering signals, then there is very high probability that one or more of the three more distant sites will be blocked.

The effective power of the unwanted signal is that power within the bandwidth of the spread spectrum receiver. Therefore, the above applies to narrow band and spread spectrum interferers alike.

Spread Spectrum Communication Systems and Location Systems

It is useful to point out the difference between a spread spectrum communication system and a spread spectrum location system with respect to the above considerations. In order to achieve a reasonable capacity, a communications system uses CDMA (code division multiple access) but in order to overcome the 'near-far' problem, it needs to employ power control of the transmissions. (Indeed the use of CDMA increases the near-far problem because units are simultaneously transmitting on different codes). Thus, in order to minimize interference, a mobile is designed to transmit at the minimum level that is needed to reach a receiving site. However, for a communications link, the transmitted signal need only be received at one site, whereas for a location system, the signal needs to be received by at least four and preferably six sites. Therefore, power control is simply not advantageous in a location spread spectrum system.

IV. Capacity Control Mechanisms

As discussed previously, in order for the system to provide the necessary accuracy and capacity and control out of band emissions, it is highly desirable to include not only the forward command links, but also a high capacity ancillary communications service within the same allocation. In order to accomplish all of these purposes it is necessary to employ a combination of techniques based on both frequency and time division schemes.

The level of the sidelobe interference in the allocated bandwidth is such that simple coexistence of other channels is not possible without